GaAs Photocathode chamber status and
Time variation of the QE status

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A0 Photoinjector Meeting
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Motivation

• NEA GaAs photocathodes are used for
  • High Quantum Efficiency
  • Spin Polarized Electrons

• These cathodes have only worked in DC guns. RF guns have not supported cathodes beyond a few RF pulses before the QE dies. The causes death are attributed to (but not proven to be)
  • Bad Vacuum (DC guns operate 1e-10 torr, RF guns 1e-9 torr at best!)
  • Ion Backbombardment
  • Electron Backbombardment (RF guns only)

• There were 4 candidate projects for trying to get NEA GaAs cathodes to work in an RF gun
  • Cryogenically-cooled NG-RF-gun, no longer thought to be viable solution.
  • HOM gun – SLAC was pursuing w/John Lewellen of ANL, but program shifted away from this.
  • Plane Wave Transformer gun – open RF structure, should have good vacuum
    • A0 is “working” on this
  • SRF gun – amazingly good vacuum, big irises alleviate electron bombardment
    • being pursued by Ben-Zvi’s group at BNL
History as I know it

• The prep chamber was acquired as the result of an SBIR Phase I with AES in 2005. AES provided the vacuum chamber and a long bellows actuator.

• The goal of that SBIR was to place an NEA GaAs Photocathode in a cryogenically cooled, normal conducting gun.
  - Phase II was not awarded, experiments showed that this was not a good solution

• DULY Research Inc. is currently producing a Plane Wave Transformer gun (SBIR Phase II)
  - FNAL has agreed to help with the “cold” RF tests and tuning, High power testing, demonstrating cathode survival
  - The last time I talked to David Yu, the “timeline” was such that they would be wanting to do some cold tests and tuning in early 09.
    - That was over 6 months ago. I haven’t spoken to him since.
    - He would not even give a rough guess as to when the gun would be completed…..

• I built a GaAs cathode prep chamber in the back of the control room.
  - It has not been fully commissioned – there was trouble with the collector.
  - I did measure photoelectrons, but was not able to measure a QE since I was unsure of extracting all of the electrons.
  - I never did prepare a full cathode with it.
  - In short – I have not looked at it since summer 2007
How it is supposed to work, what is there

Everything is there to prepare a cathode:

1. Cut GaAs wafer exist, as do uncut wafers and everything needed to cut a wafer.
2. GaAs wafers are soldered to the stalk with indium and a stalk heater.
   a) Heater is calibrated with a termocouple.
   b) Indium is available.
   c) One is currently in the chamber – I’d change it if I were you.
3. Vacuum is typically low 1-e9, high 1-e10 range, RGA and Ion Gauge installed on chamber.
4. Stalk heater heats cathode to clean surface. (600 C)
   a) Gas bleed cools the back of the stalk, feed with LN2 boiloff.
5. H2 cracker installed to further clean wafer surface.
   a) H2 stored in a lecture bottle in H2 gas shed – see Ray Lewis/ Elvin
   b) Procedure for transferring gas from lecture bottle to portable minibottle exists – see Ray Lewis/ Elvin
6. Cs getters exist/installed to Cesiate the surface.
7. NF3 variable leak valve installed to “oxidize” the surface.
   a) NF3 stored in lecture bottle in gray cabinet in gas shed outside of A0 – see Ray Lewis/ Elvin
   b) Danger Danger Danger. MSDS available.
   c) Procedure for transferring gas from lecture bottle to portable minibottle exists – see Ray Lewis/ Elvin
8. Diode laser, and mount exists with polarizer to vary laser power.
9. Collector plate is biased as high as ~1kV.
   a) This suffers from bad design. I was not able to reach a point of “saturation” where the photocurrent was not dependant on the collector voltage.
   b) The latest iteration of the collector is installed – a collector is not a sheet and not a ring. This has not been tested yet.
10. Cathode Current is measured off of the cathode stalk. (that way the collector does not need to collect all of the electrons, just pull them off) – Keithley electrometer for that.
11. I did have notebooks by the chamber with all sorts of goodness in them – maybe Jamie or Elvin have those if they are not there.
Future direction for the setup

1. Finish Commissioning. Maybe improve the design some
2. Produce a cathode with a decent QE and lifetime (24 hours)
4. Measure the “dark” QE lifetime – that is same the QE at 1 hour intervals, leave unexposed to light
5. Do it again and again.
6. Once the PWT gun arrives and is conditioned/commissioned put a GaAs photocathode in it and measure the QE. SLAC’s cathodes have 8 hour lifetime in their gun.

People to talk to in the wider world for help, assistance, guidance.
Yulin Li – Cornell (I visited him for 10 days to learn to make cathodes).
Matt Poelker – Jlab (he is eager to collaborate)
Axel Brachmann, Jym Clendenin - SLAC
Time Dependant QE – with Walter Hartung

Quantum Efficiency seen to change vs. time depending on solenoid settings
What we know – the Cliff Notés Version

• When the QE increases, a spike in dark current is seen AFTER the RF pulse is turned off (but not decayed away – but very small).
  • If you turn on the RF slowly (i.e. in about 2 us or so), you will see the spike at the beginning of the RF pulse too.
• The QE grows a factor of 2, with a time constant of about 1 hour.
• When the QE decreases, there is no spike in dark current.
• Whatever the QE does, so does the dark current.
• It is thought that this spike is multipacting in the gun. There is lots of circumstantial evidence and modeling by DESY that supports this hypothesis. This spike is the result of the multipactoring electrons at no longer being trapped and exit the gun.
• It is thought that the multipactoring “cleans” the surface of the cathode and increases the
• The multipactoring only happens at low field – estimated to be around ~1 MV/m. This is determined by an empirical model of the multipactoring based on simulation and a measurement of the appearance time of the spike.
• The charge in the spike, and the appearance time after the RF pulse is turn off can be adjusted by varying the solenoid currents.
• The Fowler-Nordheim parameters (dark current vs. cathode field) were measured before and after intervals of running with round beam settings
  • They imply that the effective emitting area grows for the first several hours, while the field enhancement factor decreases at the same time.
• INFN looked at sources of dark current in the DESY gun and there are thought to be 2 trouble spots
  • The infamous RF spring.
  • The edge of the Cs2Te coating on the plug, especially if the cathode looks crummy.
• The cathode plane of the gun looks like somebody went crazy with a screwdriver on it. The plug (to my recollection) looked halfway decent.
• For more info:
  • PAC05 – WPAP041 – Fliller, Edwards, and Hartung.
Future directions for TDQE

- My personal feeling is that this is pretty well understood what is going on, though some questions remain.
  - Is this really beneficial? Are we slowly destroying the gun or cathode?
  - Need to understand the nature of the spike – energy, size, etc.
  - Where is the multipactoring actually occurring?
  - Is there a way to move the solenoids to remove the multipactor AND not hurt the emittance?
  - Is there a multipactor condition in the new gun?
- Of course some operational questions remain
  - What is the QE and dark current?
    - I suspect that QE is down and dark current up from my last measurements